DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS

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OF THE

BEACH EROSION BOARD

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DEPARTMENT OF THE ARMY
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TIDAL CURRENT METER

The following article is the compilation of correspondence between the Beach Erosion Board and the Bureau of Reclamation in Denver, Colorado. It is presented to bring the findings to the attention of research workers and others having an interest in measurement of water velocities. The development and testing of modified forms of the Pegram Meter was done under the direction of Walter H. Price, Chief, Engineering Laboratories Branch, Design and Construction Division, Bureau of Reclamation, Denver, Colorado. For a discussion of the Pegram Meter reference is made to the article "Somervell on Effect of Turbulence on Current Meters," Trans. ASCE, Vol. 95, Pg. 800.

The Beach Erosion Board and its predecessor in the Corps of Engineers, The Board on Sand Movement and Beach Erosion, have been interested since about 1930 in finding a current meter which would not only give reasonably satisfactory measurements with varied flow, but one which would also record reversals in flow and currents of very low velocity. A meter originally designed by Dean G. B. Pegram of Columbia University appears to more nearly approach these requirements. The original Pegram meter consisted basically of a very lightweight 4-bladed propellor mounted in glass bearings on a horizontal shaft. The propellor was made to have as nearly neutral buoyancy in water as possible by making a sealed hollow hub. Revolutions of the propellor for this meter were counted and recorded electrically by fitting two poles on the frame of the meter, insulated therefrom, and connecting them to a recording galvanometer. Two opposing blades of the propellor were fitted with rubber tips, the passage of which past the poles caused a characteristic mark on the recorder.

The Beach Erosion Board has made limited use of the Pegram meter in its laboratory research studies, and due to the instruments relatively delicate and critical structural members, it has never been adapted to extensive use in the field. However, the Bureau of Reclamation has recently developed and made certain modifications to the design of this meter and has successfully employed it for measuring flow in channels under tidal influence. Facts concerning its development and use of the modified meter were recently furnished by the Bureau of Reclamation.

The meter as modified by the Bureau of Reclamation is usable for more applications than the original design because of its more rugged construction, but it still employs the basic principles of operation of the Pegram meter. The Bureau design was devised to measure the net flow in the Delta Cross Channel, which is an artificial channel connecting the Sacramento River with Georgiana Slough in the Central Valley of California. Both natural waterways are subject to tidal influence, and consequently the flow

in the artificial channel fluctuates through an imposed tidal cycle. Further contemplated use for the meter by the Bureau is the making of net flow measurements over a number of tidal cycles in other channels of the Delta, thereby obviating large survey crews working for prolonged periods with conventional current meters. Principal requirements governing the development work were to produce a meter which would measure flow in either direction without physical rotation of the entire meter, and one which would produce a recording so that it could operate unattended. The predetermined velocity range was from 0 to 5 feet per second, the aim being to measure as close to zero velocity as possible. Calculations from tidal cycle measurements showed that should the meter not indicate velocities under 0.25 of a foot per second, less than 1 percent of the net total transferred volume would be unrecorded.

Figure 1 shows the first meter built in the Bureau's shops. This meter was installed in the cross channel in the fall of 1952 and functioned satisfactorily for a continuous period of five weeks. Figure 2 shows a further modified design which was used in the summer season of 1953. The frame as shown by Figure 2 is 11 1/4 inches in diameter and has been strengthened by adding a circular plate immediately below the coupling of the supporting pipe. This plate is of such a diameter as to allow anchoring to the stainless steel electrode holders. It serves to reduce the moment at the coupling itself by distributing the load to the rings at a distance away from it. A stud was incorporated into the coupling to allow use of 1-inch double-strength pipe instead of 1/2-inch pipe. In order to prevent loss of the rotor assembly in case floating debris breaks a pivot, there is attached to each pivot housing a circular ring of stainless steel. Each ring has a slide fastener to position the ring half way up and around the hub end of the rotor assembly, but does not, of course, have contact with the hub end.

In an attempt to reduce bearing friction, a synthetic sapphire jewel bearing was substituted in the bearing housing for the pivot ball bearing of the original Bureau design. Outside dimensions of the bearing housing remained the same, but the inside aperture was made to fit the mounted jewel as received from the manufacturer. When the jewel is used the pivot point must be correctly ground to fit the cup of the jewel. However, jewel bearings are no longer being used in the modified meter. The jewels should have an advantage over ball bearings since they would tend to be self-flushing and better resist the corrosive action of salt wear. However, although wearing qualities under laboratory conditions seemed good, in field operation floating debris strikes the meter frame causing a momentary distortion which allows the pivots to fall free of the jewel cups. Upon springing back into normal position the pivot point is apt to crack the jewel.

In the modified meter shown in Figure 2, the vanes were enlarged, new inner end dimensions being 1 inch instead of 7/8 inch, and outer ends being 2 inches instead of 1-1/4 inches. The length remained the same. Spacing between the insulator and the electrode was set at 0.03 of an inch.

This small clearance assures a positive reaction on the bridge balance of the electronic component.

The operation of the wide-vane rotor in the summer of 1953 showed that the pivots to which Stoody #6 hardfacing had been applied seemed to wear faster than those used in the rotor with narrower vanes. Later examination by means of hardness tests revealed that the facilities for applying the hardfacing to a stainless steel pivot body did not permit the necessary degree of temperature control. As a result the pivot often had a hardness lower than either the stainless steel body or the hardfacing. This would account for one set of pivots exhibiting a reasonable wear record while a following set would fail in a very short time. The most satisfactory pivot at the present time is one with a stainless steel body and a point of Stoody #6 hardfacing set into the body. This unit is used in combination with the pivot ball bearing units.

Changes in the electronic recording circuits were necessitated when it was found that the meter was sensitive to the amount of total dissolved solids present in the water. Revised circuits are shown in Figure 3. The form now in use cannot be moved from one location of a certain dissolved solids concentration to another of different concentration without making considerable adjustments. If the new dissolved solids count were many times that of the original station some alteration of the circuits might be required.

Experiments are now being carried on to eliminate the sensitivity to dissolved solids. Progress thus far has shown that use of electromagnets as electrodes and vane feet of nonmagnetic metal can probably be developed to a satisfactory standard. It is hoped that with a few minor changes in the counter circuit meter, registration will no longer be influenced by variation in total dissolved solids content of the water in which it is used. If present experiments prove this to be the case the meter will be suitable for wider application. Figures 4 through 8 are calibration curves for all meter assemblies rated to date by the Bureau of Reclamation.

Figure 4 is the calibration curve for the original Bureau-designed meter (Figure 1). This meter would not operate consistently for velocities under 0.14 of a foot per second. The curve is linear as was the case for the Pegram meter, and for all other assemblies tested. No attempt was made to rate the meter above 5.5 feet per second. Pivot ball bearing units were used for all tests as well as for the period of use in the cross channel. The pivots were well worn after five weeks in the cross channel, yet a recalibration showed the angular shift in the rating curve slope to be very slight. It would seem, therefore, that so long as the pivot can still turn freely in the bearings without danger of dropping free of them, the condition of the pivot is not a critical factor. It is believed by Bureau engineers that hardfacing the entire pivot point will permit almost indefinite use because wear should proceed only until the groove in the point is of sufficient area to carry the maximum thrust encountered.

Figures 5 and 6 and Figures 7 and 8 should be considered in pairs. Two modified meters were built for use in the modified frame of type shown in Figure 2. They have been designated on the curves as Meter No. 1 and Meter No. 2. Meter No. 1 was the narrow-vane meter. Meter No. 2 was built of the hub ends and spiders from the original meter and a new axle and wider-vane assembly. Both meters were rated for pivot ball bearings and jewel bearings. There is no difference, of any practical significance, in the calibration curves for the two types of bearings in the same meter. There is a difference in curves for Meter No. 1 and Meter No. 2, which fact serves only to emphasize that each meter of any design must receive a separate calibration. That there is no comparable difference in bearing types is significant, and seems to indicate that friction had been reduced to a practical minimum with use of the pivot ball bearings. The lower limit of operation for both meters is 0.12 of a foot per second.

The original meter with the narrower vanes was almost buoyant in water. Adding width to them, of course, was done at a sacrifice of that buoyancy. It is believed that restoring the original vane size would not materially aid in obtaining operation at velocities lower than 0.12 of a foot per second. The vanes had been enlarged in an attempt to gain a higher turning moment, but it appears that the maximum usable area had been reached on the first meter. It should be recognized that the vane shape was decided upon through consideration of geometric factors alone, and that no propeller design theories or practices were employed.

It is pointed out that no provision has been made for indicating the direction of flow on the recording, as was done with the Pegram meter. This was not necessary because the curve of velocity drawn by the recorder is roughly the sine curve, and comparison with the curve shown by a tidal stage recorder located nearby, readily sets the direction of flow. The pattern is repetitive, and changes in direction take place slowly over periods of 2 to 6 hours. Without the directional feature it is possible to use insulators on all vanes to obtain a higher input count to the counter circuit. This is an advantage, particularly at low velocities.

In summary, the Bureau of Reclamation has a current meter which satisfies its present requirements. Though some additional development work might produce an improved design which would operate at lower velocities, it contemplates no further effort in that direction.

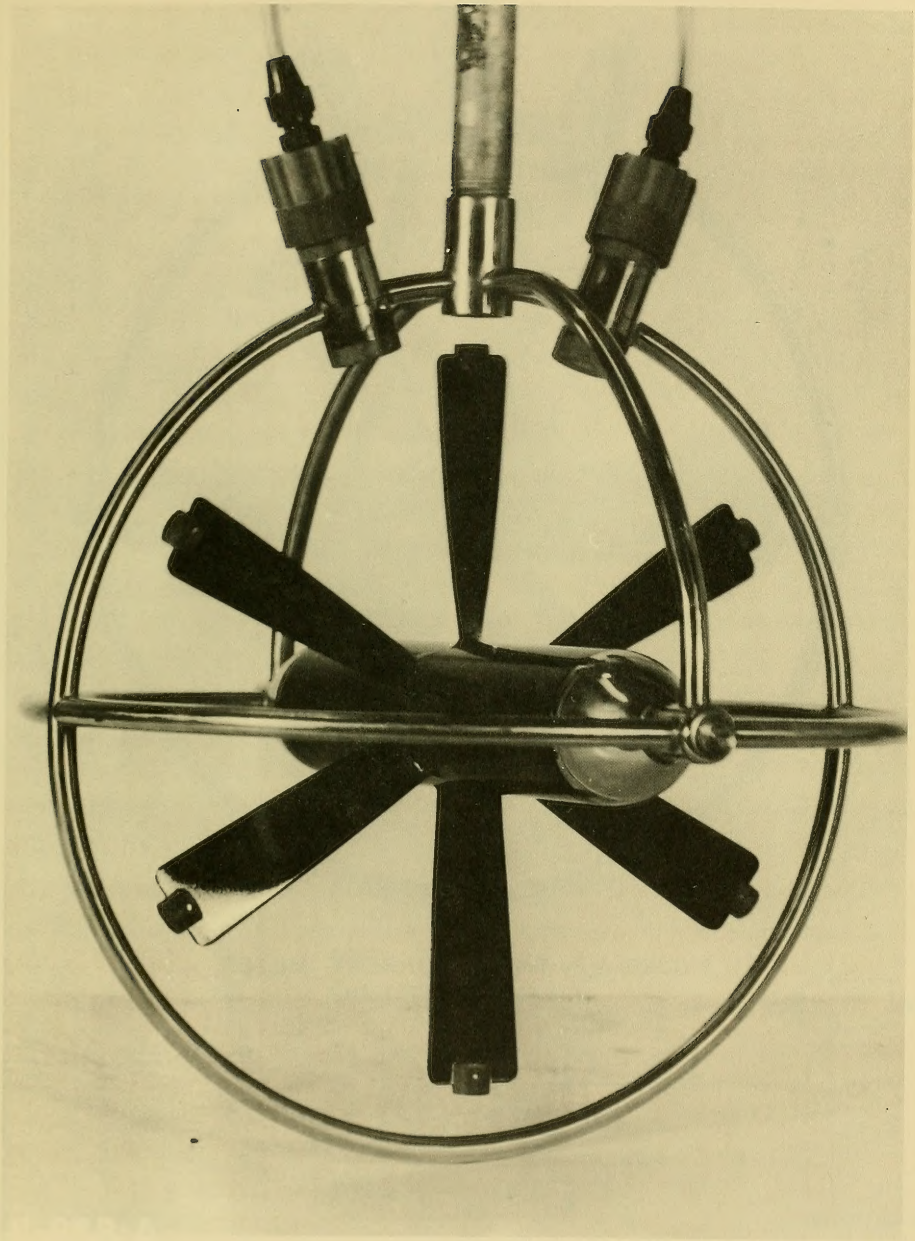


FIGURE 1 - TIDAL CURRENT METER
(DEVELOPMENT BY BUREAU OF RECLAMATION)

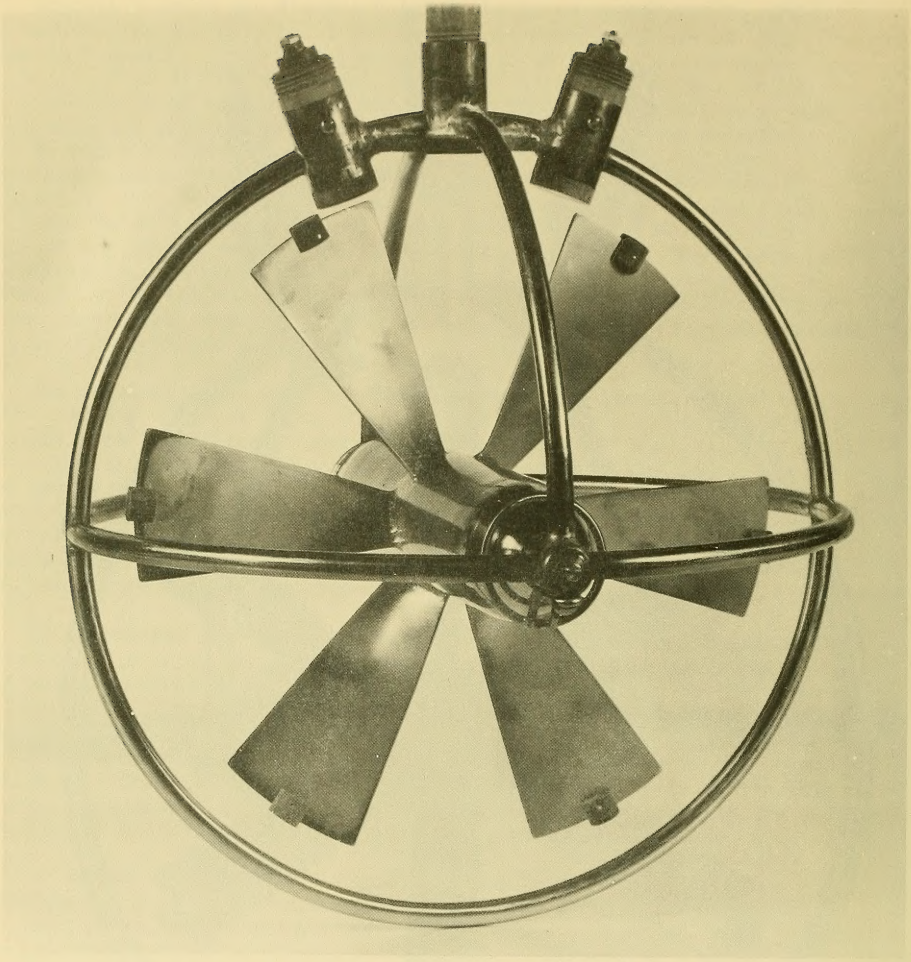
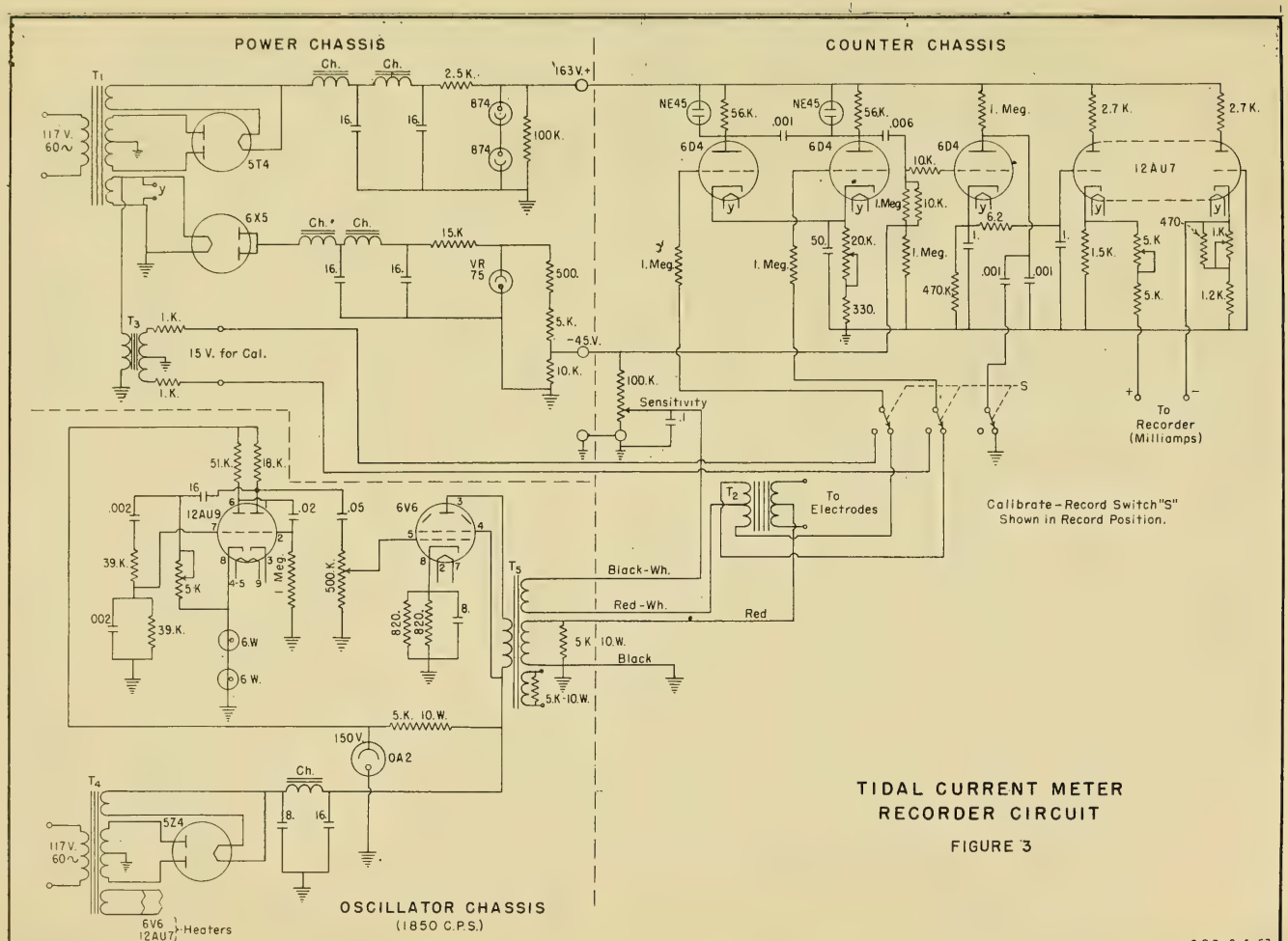


FIGURE 2 - TIDAL CURRENT METER
(FINAL MODIFICATION)



TIDAL CURRENT METER
RECORDER CIRCUIT

FIGURE 3

C.R.D. 8-4-53

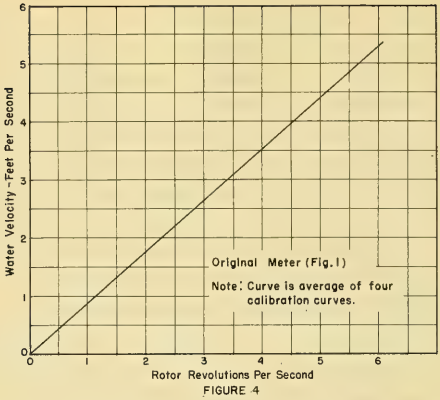


FIGURE 4

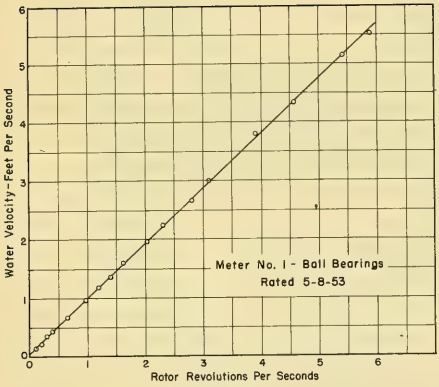


FIGURE 5

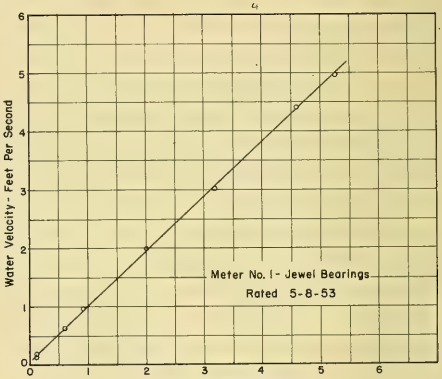


FIGURE 6

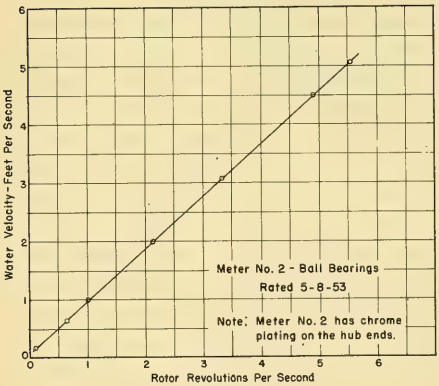


FIGURE 7

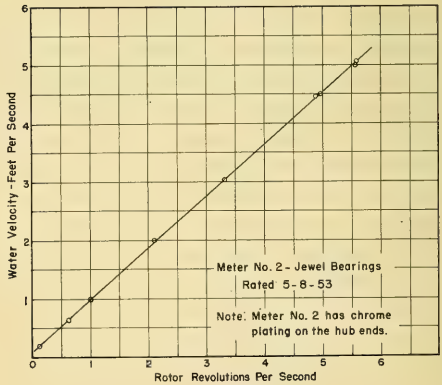


FIGURE 8

CALIBRATION CURVES - TIDAL CURRENT METERS

PROGRESS REPORTS ON RESEARCH SPONSORED BY
THE BEACH EROSION BOARD

Abstracts from progress reports on several research contracts in force between universities or other institutions and the Beach Erosion Board, together with brief statements as to the status of research projects being prosecuted in the laboratory of the Beach Erosion Board are presented as follows:

I. University of California, Contract No. DA-49-055-eng-8, Status Report No. 13, 1 Dec. 1953 through 1 March 1954.

The report entitled "Bore Hole Studies of the Naturally Impounded Fill at Santa Barbara Breakwater, California", Institute of Engineering Research, Waves Research Laboratory, Technical Report Series 14, Issue 14, by Parker D. Trask and Theodore Scott, was submitted to the Beach Erosion Board on 18 January. Insofar as is known, this is the first attempt that has been made to drill holes through a natural accumulation of sand above a shallow water offshore area in order to study sedimentary processes.

The mechanical analysis of the sand samples collected during the course of the survey of the movement of sand around rocky promontories of Point Arguello, Point Conception and Point Dume in Southern California is, as of 28 February 1954, approximately 35 percent complete.

During the latter part of February a series of sand samples taken at mathematical intervals was obtained at two localities off the coast at Point Reyes, in order to determine the variability of individual samples taken upon a beach which was known to be irregular in composition. Previous studies of sample errors have generally been made upon beaches that ostensibly vary very slightly. This study at Point Reyes was carried out with the object of showing how reliable an individual sample could be upon a beach known to be irregular in composition.

II. University of California Contract No. DA-49-055-eng-17, Status Report No. 3 - 1 October to 31 December 1953.

The experimental work with a movable bed was completed and a report submitted entitled "Sand Movement Mechanics in Deep Water" by Madhav Manohar. Part I of this report dealt with the mechanics of sand movement on sandy beds in relatively deep water due to the action of oscillatory waves of small amplitude and long wave length. On the assumption that the bottom water oscillations were nearly simple harmonic motions, sand movement mechanics were studied by oscillating a section of the bed horizontally through still water. Only that part of the sediment load which rolls, or creeps along the bottom, as distinguished from suspended load which is carried in the fluid in suspension was considered in this report. Its initial and general movement, the critical velocities and horizontal amplitudes required for such movements, the conditions of flow at the interface - whether laminar or turbulent - were experimentally

measured and analyzed theoretically for grains of various sizes and densities.

Part II of this report pertains to ripple formation. The term ripples is used to indicate the systematic series of undulations or waves that are observed to form on the bed at certain critical velocities. Natural ripples are formed at velocities greater than those required for general movement, where natural ripples are those generated directly on a smooth bed by the intense movement of the particles, and not by conspicuous external obstructions which tend to hasten their formation even at much lower velocities. It was the objective of the explanation in this part of the report to examine the phenomenon of natural ripple formation. In this study experimental observations were limited to the initial formations of the natural ripples and as such experimental analysis was limited to that stage.

This report will be published as a Technical Memorandum of the Beach Erosion Board during the summer of 1954.

III. University of California, Contract No. DA-49-055-eng-31, Status Report No. 2 - 1 Nov to 31 Jan 1954.

1. The installation and calibration of instruments for measuring waves, wind, pressure drop and wind tides has been completed.

2. The following measurements are made for each experimental run:

   a. The wind set-up at 5 locations along the center line of the channel.
   b. The vertical wind velocity distribution at 3 locations in the channel by use of a pitot tube.
   c. Wave measurements at 4 locations along the channel. At each of these 4 points of measurement a continuous surface time history is obtained over a time period of approximately one hour so that it is possible to evaluate the data for mean, significant and maximum waves as a function of the duration of the wind.

3. Experiments in progress involve the following wind and channel conditions:

   a. Five different average wind velocities.
   b. Seven different still-water depths.
   c. All the above mentioned conditions are to be conducted for both rough and smooth bottoms of the channel.

IV. Scripps Institution of Oceanography, Contract No. DA-49-055-eng-3, Quarterly Progress Report No. 18 - Oct. to Dec. 1953.

The variability of orbital velocities is being compared with the variability of the waves generating them. Comparisons are made from 20-minute records which represent widely different conditions.

The underwater work with reference rods has indicated changes in the bottom level in excess of 2 feet in shallow water; changes in water deeper than 30 feet have been very slight.

The observation and measurement of ripples has been extended to include two coarse sand areas. The large size of the ripples in coarse sand permits direct observation of grain motion and selective sampling of sand from ripple crest and trough. Generally sand from the ripple crest is slightly coarser, better sorted, and skewed more toward coarser particle sizes than that from adjacent troughs.

Between 30 November and 15 December a submarine slide took place in the Sumner Branch and South Branch of Scripps Submarine Canyon. The slide was first reported by divers and was confirmed by an echo-sounding survey which showed that the maximum change was a deepening of 9 feet. The divers had reported larger changes but these were in the narrow gorge, where echo-sounding is inaccurate. Stakes have been driven into the canyon walls which will allow comparative measurements to the canyon floor.

V. The Agricultural and Mechanical College of Texas, Contract No. DA-40-055-eng-18, Quarterly Report for period ending 31 January 1954.

1. Field Operations. Field operations were continued at the Sun Oil Pier at Caplen, Texas, simultaneous 20-minute records being taken twice daily at both shoreward and seaward end of the pier.

A third recorder has been installed temporarily on a Magnolia Oil platform south of Morgan City, Louisiana, and records are being taken periodically. The mean water depth at this site is 40 feet.

The analysis of all wave records obtained at Pure Oil Structures A and B has essentially been completed. The analysis of wave records obtained at the Sun Oil Pier and Magnolia platform is in progress.

2. Theoretical Investigations. Computations involving the combinations of wave generation and wave energy loss due to bottom friction have been completed for the case of a shallow bottom of constant depth. Computations for a bottom of constant slope have continued.

VI. New York University, Contract No. DA-49-055-eng-32.

Work was continued on the development, design, and manufacture of a spectrum analyser for wave records, and on the statistical analysis of hindcast wave data along the Atlantic Coast obtained by the Neumann-Pierson methods. In addition, a report "On Ocean Wave Spectra and a New Method of Forecasting Wind-Generated Sea" by Gerherd Neumann was published as Technical Memorandum Number 43 of the Beach Erosion Board.

VII. Massachusetts Institute of Technology, Contract No. DA-49-055-eng-16. 5th Progress Report dated 12 February 1954.

1. To determine the proper statistical sample size of the test sediments, a study was made of the motion of 1/8" cellulose acetate spheres in individual sample sizes of 20, 30, 40, 50, and 60 spheres under the action of the same wave. On the basis of the derived set of distribution curves as a function of time and distance, a sample size of 50 was selected as being the smallest having the correct statistical distribution.

2. Three more tests were carried out to check reproducibility of results with this sediment sample size, and also the effect of the last wave generated in each increment of time. It appears, on the basis of the first increment where all samples had the same starting position, that a number of runs will have to be averaged to give the correct velocities.

3. It was found that for each combination of wave geometry, beach and particle properties, there is a point on the beach slope at which the gravity force is in balance with the drag forces on the sphere. This point divides motion of the particles into onshore and offshore transportation.

4. Recording the transverse positions of the particles showed a steady migration of the center of gravity of the sample toward one wall. This may be due to the effect on the wave motion of slight misalignments in the channel walls.

VIII. Waterways Experiment Station, Vicksburg, Mississippi.

Wave Run-up on Shore Structures - Overtopping tests on a step-faced seawall with a seaside slope of 1 on $1\frac{1}{2}$ and a beach slope of 1 on 10 were completed for the 25 and 34-foot depths, and for the 3- and 6-foot crest elevations for the 29.5 foot depth. Testing was then discontinued due (1) to lack of funds, and (2) to permit initiation of testing on a 1 on 3 smooth slope similar to the Lake Okeechobee levee section. An expanded program of wave conditions will be used in these new tests.

Effect of Inlets on Adjacent Beaches - This test, having in 450 tidal cycles successfully reproduced several cycles of migration of the tidal inlet, was discontinued, and the results of the test are now being analyzed.

IX. Beach Erosion Board, Research Division, Project Status Report for Quarter ending 15 March 1954.

In addition to the research projects under contract to various institutions which are reported on above, the Research Division of the

Beach Erosion Board is carrying out certain projects with its own facilities. The main unclassified projects have been described in previous numbers of the Bulletin, and a short description of some of the work accomplished through the last quarter is given below.

Project ESMOND - A final report was prepared and scheduled for publication in the summer of 1954. A search is being made for reports of prior work (prototype or model) on the maneuvering of ships through fluids having densities (and viscosities) different from water, and information supplied bearing on this project would be appreciated. A short field test was made by the Philadelphia District on the maneuverability of an oil tanker in the Delaware River, and particularly in travelling over and through mud shoal areas.

Study of Reforming of Waves After Breaking - A wave tank study has been initiated to define the conditions under which waves will reform after breaking, and the relationship between the energy transmitted forward by the initial unbroken wave and that of the reformed wave.

Instrument Development - A sinusoidal dynamic calibrator is being made to enable determination of the time effects of moving water (as meniscus) on wave gage calibration, particularly for waves of very low amplitude.

Routine progress, testing, and analysis, has been made on the other projects being carried out by the Research Division. In addition, a small project was carried out for the Fish and Wildlife Service and the Geological Survey involving the testing and development of small dampeners which could be placed on a sand flat or beach and allow tidal circulation but break up the oscillatory wave currents which mold the bottom into a ripple pattern and constantly stir the top layer of sand; these dampeners would provide a shelter where seed clams could get an anchor without being disturbed by the moving sand. Several types were developed that were deemed worthy of further study, and prototype field trials of these were recommended.

Beach erosion control studies of specific localities are usually made by the Corps of Engineers in cooperation with appropriate agencies of the various States by authority of Section 2 of the River and Harbor Act approved 3 July 1930. By executive ruling the costs of these studies are divided equally between the United States and the cooperating agencies. Information concerning the initiation of a cooperative study may be obtained from any District or Division Engineer of the Corps of Engineers. After a report on a cooperative study has been transmitted to Congress, a summary thereof is included in the next issue of this Bulletin. Summaries of reports transmitted to Congress since the last issue of the Bulletin and a list of authorized cooperative studies follow.

SUMMARIES OF REPORTS TRANSMITTED TO CONGRESS

HAMPTON BEACH, NEW HAMPSHIRE

The area studied is located in the Town of Hampton in the southeast corner of New Hampshire. It comprises the shore of the Atlantic Ocean between the headland known as Great Boars Head and the entrance to Hampton Harbor, a distance of 1.8 miles. The shore area is extensively developed for recreational use. The permanent population of Hampton is about 2,850. The summer population was estimated at 21,500 in 1945, since which date additional facilities have provided for a larger summer population. Large numbers of daily visitors also use the beach. The shore is owned by the State, except for about 0.2 mile which is owned by the Town and leased for private cottage use.

Hampton Beach consists of a barrier bar or spit extending southward from Great Boars Head, the remains of a glacial drumlin. Erosion of that headland formerly supplied ample material to the beach to the south but protective works and the residue of coarse material have reduced the supply of material to the beach. Consequently the beach has slowly deteriorated. The problem area is about 1.3 miles in length between Great Boars Head and Haverhill Street. The shore boulevard along this area is partly protected by a seawall. The width of beach seaward of the wall decreases in width northward, and the size of beach material increases in that direction from fine sand to cobbles and boulders at Great Boars Head.

Tides in the area are semi-diurnal, the mean range at Hampton River being 8.3 feet. The spring range is 9.6 feet. The maximum tide of record at Portsmouth, about 12 miles to the north, was 3.9 feet above mean high water. Tides 3 feet or more above mean high water occur about once in 2 years.

Hampton Beach is exposed to waves from the northeast, east and southeast. The fetch to the northeast is limited by Nova Scotia, about 250 miles distant, but the Isles of Shoals about 11 miles away also afford

some protection from waves from the northeast. The fetch to the east is unlimited. Cape Ann, 17 miles to the southeast, limits the fetch in that direction. Storm waves which cause the greatest movement of beach material are those from the northeast . The predominant direction of littoral drift is southward.

The Division Engineer and the Beach Erosion Board concluded that the most suitable plan for protecting, restoring, and improving Hampton Beach north of Haverhill Street consists of direct placement of sand fill along the shore to widen the beach to a general width of 150 feet, with an added 25-foot widening along 1,250 feet of the northern end of the fill area. They also found that protection and improvement of Hampton Beach are justified by evaluated benefits and recommended adoption of a project by the United States authorizing Federal participation, subject to certain conditions, by the contribution of Federal funds in an amount equal to one-third of the first cost of the plan. The estimated total cost and Federal share are respectively $420,000. and $140,000.

The Chief of Engineers concurred in the views and recommendations of the Beach Erosion Board.

SELKIRK SHORES STATE PARK, NEW YORK

Selkirk Shores State Park comprises about 1 mile of shore at the southeastern corner of Lake Ontario. It is located in the Town of Richland, in Oswego County about 15 miles northeast of Oswego Harbor. It is conveniently located with respect to the population centers of Oswego Syracuse, Rome and Utica, which have a combined population of over 385,000 The park has been developed with cottages, camping facilities, bathing beach, picnicking and parking areas.

The shore in the vicinity of the park comprises bluffs of glacial till alternating with barrier beaches across the drainage courses. The exposed drumlins south of the study area furnish gravel and cobbles to the shore. The barrier bar fronting Grinstone Creek is composed of this material. North of this bar the bluff rises gradually to a maximum height of 44 feet, thence decreases to the bar fronting the Salmon River. This bar has a gravel and cobble beach backed by sand dunes which have a maximum height of 60 feet. The streams flow through marshes and furnish no material to the shore.

Lake Ontario is about 190 miles long and 50 miles wide. The mean lake level for the months of March to December is about 2 feet above the established low water datum. The highest lake stage and the highest monthly mean recorded at Oswego, New York, are respectively about 6.2 and 5.3 feet above low water datum. Storms cause changes in lake levels as winds move the water toward the ends of the lake. The design lake stage is 6 feet above low water datum. Of winds which generate waves affecting the area, those from the west have the greatest fetch, about 170 miles. During severe storms with a frequency of about once a year, waves may range up to 12 feet in height in deep water, but ordinarily waves of this height would break before reaching shore structures.

Storm waves which cause the greatest movement of beach material are those from the west. The predominant direction of littoral drift is northward.

The Division and District Engineers and the Beach Erosion Board concluded that the most suitable plan for the protection of Selkirk Shores State Park consists of: (a) the construction of an outlet structure, consisting of two jetties to form an outlet channel to carry Grindstone Creek through the barrier beach and into the lake to prevent migration of the creek mouth and to stabilize the adjacent shore; (b) the restoration of approximately 900 feet of beach frontage by alteration of an existing groin, construction of a new groin and placement of sand fill. The southerly half of the beach area would be compartmented between the proposed outlet structure and the existing groin which would require alteration. The northerly half would be compartmented between the same existing groin and the new groin; and c) protection of the shore northerly of the beach areas by means of a roadway-type quarry-run stone revetment. They found that protection and improvement of the shore at Selkirk Shores State Park are justified by evaluated benefits, and recommended adoption of a project by the United States authorizing Federal participation, subject to certain conditions, by the contribution of Federal funds in an amount equal to one-third of the first cost of the plan. The Board believes that stone would be preferable to steel for construction of the new groin. The Board also considered that in order to avoid scour north of the new groin, the revetment adjoining the groin should be widened to 25 feet tapering thence to 10 feet at a distance of 25 feet to the north.

The Chief of Engineers concurred in the views and recommendations of the Beach Erosion Board.

STATE OF OHIO, EUCLID TO CHAGRIN RIVER

The area studied is located in Cuyahoga and Lake Counties on the south shore of Lake Erie adjacent to and east of Cleveland, Ohio. It lies between the Cleveland-Euclid boundary and Chagrin River a distance of about 8 miles. The area includes the shore line of the city of Euclid, the villages of Willowick, Lakeline, Timberlake and a portion of Eastlake. The property along the shore line of the study area has been developed mainly for private residential and recreational purposes. Publicly owned portions of the shore are limited to Euclid City Park, 300 feet of frontage at 23131 Lake Shore Boulevard also owned by the city of Euclid, and street ends. Euclid City Park is the site of a sewage disposal plant, and a beach impounded there by the outfall structures affords ample protection to this frontage. The other 300 feet of city-owned frontage is undeveloped and eroding at a moderate rate..

The shore line of the study area consists of easily eroded bluffs of boulder clay and shale varying from 25 to 40 feet in height, fronted by sand beaches up to 200 feet in width at mean lake level. The wider beaches are generally the result of impounding of littoral drift by structures built for other purposes such as sewer outlets or navigation

improvements. The narrow natural beaches are submerged at high lake levels. It has been estimated that about 20 percent of the bluff material within the study area is suitable for beach building. Erosion of the beach and bluffs along the shore of the city of Cleveland east of Cleveland Harbor and in parts of the study area is now supplying considerable beach material by means of the slight dominance of eastward littoral drift. Beaches west of the study area have been steadily reduced in width by erosion during the past 20 years.

Miscellaneous groins, walls, and breakwaters have been constructed in an attempt to prevent erosion of the shore. Short groins have generally caused minor accretion on their west sides and have reduced recession of the bluffs to some extent, but the majority have been too short and low to be fully effective. The accretion west of the outfall structure at Euclid City Sewage Disposal Plant and the west jetty at the mouth of Chagrin River indicates an eastward predominance of littoral drift.

The mean lake level for the months of March to December is about 1.6 feet above the established low water datum. The highest lake stage and the highest monthly mean recorded at Cleveland, Ohio, are respectively about 5.2 and 4 feet above low water datum. Storms cause changes in lake levels as winds move the water toward the ends of the lake. Of winds which generate waves affecting the area, those from the northeasterly quadrant have the greatest fetch, about 150 miles, but for the ice-free period those from the northwesterly quadrant apparently have the greater effect on material movements. It is estimated that, considering the effect of wind set-up during easterly storms to be about 1/2 foot, the lake could reach a level in the study area of about 4.5 feet above low-water datum. During severe storms waves may range up to 10 to 12 feet in height in deep water, but ordinarily waves of this height would break before reaching shore structures. The maximum height of waves breaking landward of low water datum shore line at a design lake stage of 4.5 above low water datum would be 3.5 feet. Existing groins with shore ends from about 5 to 7 feet above low water datum indicate that these elevations are generally adequate to impound a low protective beach. A beach 30 feet in width between the water line at design lake stage of 4.5 feet above low water datum and elevation 8 feet above low water datum is considered the minimum necessary to protect the bluffs in the study area from erosion by wave action. In those areas where a beach presently exists, it may be built or maintained to the required minimum dimensions by construction of suitably designed groins. However, as more of the shore line is protected the natural supply of beach building material through littoral drift may be expected to decrease, and additional maintenance by adding material artificially may be necessary. In those areas where no beach presently exists and none is desired, the bluff may be protected by a seawall with top elevation of 8 feet above low water datum and the slope above armored with stone revetment to elevation 12 feet above low water datum. Protection can also be provided by a continuous belt of heavy riprap at the toe of the bluff extending up to

elevation 12 feet above low-water datum. Ice forms a protective coating over beaches during winter months, but the lifting and battering action of shifting ice floes during the spring break-up must be considered in designing shore structures for structural stability.

The District and Division Engineers concluded that there is sufficient beach material available to provide beaches of the minimum width necessary to protect the bluffs from erosion by wave action for a considerable portion of the study area. This material is presently accumulated in a wide beach that appears to have moved eastward from the shores of Cleveland to the westerly part of the study area. It can be expected to continue its eastward movement unless prevented by retarding structures. They concluded that the most economical method for the protection of a large part of the shore frontage within the study area is by constructing groins to retard the movement of this material and retain a suitable beach of minimum width for protection of the bluff, while permitting the remainder of the material to continue its movement eastward. Artificial placement of fill will be necessary to create beaches in the extreme westerly end of the study area, and at other localities after the greater part of the area has been protected. They also concluded that an overall plan of artificial nourishment would have general benefits exceeding those of other plans considered. Where no beaches now exist, nor are particularly desired, protection of the bluff can be provided by a seawall or revetment.

The Beach Erosion Board concurred generally in the conclusion that groin construction is the most economical method of protecting individual properties, provided only limited reaches of the total shore length are considered. If the entire shore is involved, the costs would be increased by an item for artificial placement of fill. The Board also noted that the estimated annual costs of the revetment and seawall plan, if constructed in lengths of over 120 feet, would be somewhat less than those of the artificial nourishment plan. However, in the absence of a natural supply of beach material continued erosion may be expected lakeward from revetments and seawalls. Moreover it noted that the costs of the artificial nousishment plan were based on available costs without complete investigation of sources and also include a liberal allowance for maintenance. Considering these factors, the Board was of the opinion that a complete investigation of sources of material and methods of placement, a study beyond the scope of the present report, should be made. Such a study might result in substantial reduction of the estimated costs of a comprehensive artificial nourishment plan. Considering also the greater general benefit that would accrue from such a plan the Board concluded that its economic justification might be found to be greater than that of any other plan.

The Beach Erosion Board recommended that local interests consider adoption of a comprehensive plan of protection by artificial placement of a sand beach, either directly over the entire length, in stockpiles or as a feeder beach near the west limit of the area, based on their own determination of economic justification. In the event that protection of individual properties is necessary, the Board recommended that private owners consider adoption of the plans of protection by groins, revetment

or seawalls, including adequate flank protection, selecting that plan most suitable to the present condition and desired use of their shore frontage consistent with the effect on adjacent shore sections. As additional protection of publicly owned shores is not warranted at this time, and existing Federal law includes no policy for Federal assistance in the cost of protecting privately owned shores. The Board recommended no Federal participation in the cost of the work.

The Chief of Engineers concurred in the views and recommendations of the Beach Erosion Board.

LAKE ERIE SHORE OF THE STATE OF OHIO

The Beach Erosion Board in connection with transmitting the last report on the continuing cooperative study of the Lake Erie shore of Ohio considered it desirable to summarize the knowledge and conclusions regarding methods of shore protection in Ohio resulting from this investigation from the viewpoint of the entire shore of the State and on a long range basis.

A typical condition found along the Lake Erie shore of Ohio is an eroding bluff of unconsolidated clay, silt, and sand. As the bluff is undercut by wave action, or sloughs due to seepage of surface water or frost action and falls to the beach, the finer fraction of the material is carried into deep water and the coarser fraction remains to form or replenish the beach. As the latter material is typically only a small proportion of the total volume, the beaches thus formed are narrow and provide the bluffs little protection against wave action.

As indicated in the reports on the several areas, one method of protecting the bluffs comprises placement of a non-erodible barrier between the waves and the bluff in the form of a seawall, bulkhead, or revetment. Such structures cause wave reflections and turbulence. In addition, by preventing erosion of the bluffs they reduce the amount of sand available for beach building or replenishment. In the absence of a natural supply of beach material, continued erosion may be expected lakeward of the structures as well as on the adjacent unprotected shores. Because of their high costs, seawalls, bulkheads, and revetments are usually used for relatively short frontages. The necessity of flank protection as adjacent shores recede increases the cost of protection by structures of these types. The continuing lakeward erosion results in steadily increasing maintenance costs. Initial and annual costs become so high that this method can be justified only for property of high valuation.

The Board has found that wave energy is absorbed more effectively by a gently sloping sandy beach than by any other method. With steeper slopes, coarser material is required for stability. With large stones the wave absorbing structure become a revetment or rubble mound with slope approaching 1 vertical to 1 horizontal.

As stated in certain of the reports on the several areas covered by the study, groins may be used to a limited extent to assist in accumulating or retaining a sandy protective beach. The amount of sand naturally available to the shore is generally insufficient to make this a feasible means of providing adequate shore protection for any extensive frontage. Where used effectively for a limited frontage it would reduce the amount of sand being transported alongshore and adversely affect an adjacent frontage.

In the absence of a natural supply of beach material, beaches can be placed or widened by artificial placement of sand on the shore. It may be placed directly along the full extent of the shore to be protected, in stockpiles to be distributed by wave action, or as a feeder beach to provide a continuing supply of material to maintain the existing beach. Where there are extensive frontages between littoral barriers, artificial supply of material frequently becomes the least costly method of preventing recession of the shore line, as the supply of material maintains the entire frontage.

An investigation of offshore deposits of sand in the vicinity of Lorain and Fairport Harbors was made in connection with a previous report. The purpose of this investigation was to locate adequate sources of sand for the construction of beaches for shore protection and improvement. Ir was found that large reserves of suitable sand are available in the deposits investigated. Further investigation may reveal additional deposits not presently known.

A complete investigation of sources of sand for beach construction and maintenance and of methods of placement was beyond the scope of the reports under the cooperative study. If a comprehensive plan of beach construction is adopted, more economical methods of placement can in all probability be developed than are presently available. The Board believed that the plan of protection by artificially placed and maintained beaches may be found to be the most econo mical method of protection for any extensive reach of shore.

As the Board did not consider the economic justification of protection for any large segment of shore including both publicly and privately owned frontages, it could not comment on the relative costs of large scale protection and the economic cost of gradual loss of land by recession of the shore at rates up to nearly 5 feet annually. The latter varies with the use of the land. Where land is developed with costly manufacturing or power plants high cost protection is warranted. In the case of unused land the cost of protection is obviously unjustified. In the latter case and where buildings can be readily moved landward as the shore recedes, or have an economic life less than the period until recession caused their destruction, an alternative solution is to permit continuing recession of the shore. In this solution, it would be advisable to restrict future construction to types having an economic life less than the period until the shore recession reaches their position.

As piecemeal protection by walls, bulkheads, and revetments is both extremely expensive and will aggravate erosion in unprotected areas, the Board concluded that protection of the shore by artificially placed beaches is the most practicable means where extensive frontages are involved. Maintenance of the beaches by artificial means is, of course an essential part of the plan. If maintained, the plan can be effective permanently. The Board believed that the annual costs of this plan on a large scale basis may be found to be less than the costs for any other plan. In addition to providing protection, the beaches would be available for recreational use. Considering all costs and benefits, the Board was of the opinion that the protective beach plan would probably have substantially better economic justification than other plans.

The Board recommended that the State of Ohio investigate sources and costs of placing suitable material and consider the adoption of comprehensive plans of protecting extensive reaches of shore by artificial placement and replenishment of sandy beaches, based upon its own determination of economic justification.

The Chief of Engineers concurred in the views and recommendations of the Beach Erosion Board.

SHORE OF GALVESTON BAY FROM APRIL FOOL POINT TO KEMAH, GALVESTON COUNTY, TEXAS

The area studied is located on the west shore of Galveston Bay about 17 miles north of Galveston, Texas. It includes the shore from April Fool Point to the mouth of Clear Creek at Kemah, a distance of about 10 miles.

The property along the shore line of the study area has been developed mainly for private residential and summer resort use. The principal centers of population are San Leon, Clifton by the Sea and Kemah. The residential population of about 1,000 along the bay shore of the study area is more than tripled by summer residents. Many additional persons visit the area over summer weekends. The shore is privately owned except for ends of public streets extending to the shore. Although some pollution of bay waters may exist, it is insufficient to render the shore area undesirable for residential use.

The shore of the study area consists of a narrow sandy beach in front of a steep eroding bluff composed principally of sandy clays. The top of the bluff varies in elevation from about 10 to 17 feet above mean sea level. Little of the bluff material is of sufficient size for beach building. Sections of the bluff slough off and fall to the beach during the rainy season. They disintegrate under wave action and most of the material is carried offshore. The short local wind waves characteristic of the bay are not of the type that would tend to return material to the shore. Over the period of record, the shore from April Fool Point to a point about 2 miles north of Edwards Point receded an average of about 4 feet annually, thence north to Clear Creek the recession averaged about 2 feet annually.

Miscellaneous revetments, seawalls, bulkheads and groins have been constructed by private owners in an attempt to prevent erosion of the shore. The ineffectiveness of groins in causing accretion indicates a lack of movement of beach material alongshore. The other types of structures have been generally effective against normal erosion, but many have failed as a result of storm wave action or flanking.

The mean range of tide in Galveston Bay is about 1 foot. The highest tide of record in the bay area was 14.5 feet above mean sea level. Tides of 5 feet or more above mean sea level occur on the average only once in about 8 years. Maximum tidal stages accompany southerly winds and minimum stages result from prolonged northerly winds. The study area is exposed only to waves generated in Galveston Bay. Due to the shallow depth of the bay at normal tidal stages, wave action against the bluff at such stages is negligible. The shore between April Fool and Edwards Points is exposed to waves from the southeast and east. Such waves are generated by south to east winds which also cause above normal tidal heights along this section of shore. At storm tidal stages over 3 feet above mean sea level, which occur on the average only once in about 2 years, waves up to about 2 feet in height probably break against the bluff. Still larger waves probably reach the bluff during the more infrequent hurricanes with tides of 8 feet or more. Such waves are the most destructive forces affecting the shore. The cost of protecting against such infrequent conditions is prohibitive. North of Edwards Point the alignment of the shore is such that it is exposed only to waves from the north and northeast. As northerly winds do not increase, but tend to reduce tidal stages, the bay is shallower than during southerly storms. Consequently, large waves break before reaching the bluffs along this shore and it is believed that the maximum wave height at the shore under those conditions does not exceed 1.5 feet.

The District and Division Engineers and the Beach Erosion Board concluded that the most practicable and economical plan of protection consists of a dumped mound of quarry-run stone with a filter blanket of shell to prevent leaching of clay from behind or beneath the mound. The minimum top elevation of the mound would be 5 feet above mean sea level from April Fool Point to Edwards Point, thence 3 feet above mean sea level to Kemah. The bank would be graded on a slope not steeper than 1 on 4 and seeded and sodded behind the top of the mound. Since the shores of the study area are privately owned and existing Federal law does not include a policy of Federal participation in the protection of such shores, they recommended no Federal participation in the cost of any protective work.

The Chief of Engineers concurred in the views and recommendations of the Beach Erosion Board.

ANAHEIM BAY HARBOR, CALIFORNIA

Anaheim Bay Harbor is located on the Pacific Ocean coast of Southern California in Orange County, about 4 miles southeast of the mouth of the Los Angeles River at Long Beach. The adjacent shore communities are Seal Beach to the west with a population of 3,558 and Surf Side and Sunset Beach to the east with a combined population of about 1,550. Orange County has a total population of about 214,000. The development of the shore communities is principally residential. The beaches are used extensively for recreational purposes.

The Seal Beach shore with a frontage of 6,100 feet is publicly owned. Adjacent to the Anaheim Bay east breakwater, there is a Federally owned frontage of 900 feet. The remainder of the Surf Side shore, amounting to 3,200 feet, is privately owned. The Sunset Beach shore, 6,200 feet in length, is publicly owned. Anaheim Bay has been developed as a harbor by the United States Navy. The entrance thereto is protected by two converging breakwaters.

The District and Division Engineers and the Beach Erosion Board concluded that the most suitable plan of protection of the shore in Orange County, California from San Gabriel River to Los Patos Avenue in Sunset Beach, comprises artificial placement of approximately 200,000 cubic yards of sand on the shore and construction of one groin at Seal Beach, and placement of a feeder beach in amount of approximately 1,000,000 cubic yards of sand at Surf Side. They found that such protection is economically justified and recommended Federal protection in an amount equal to the portion of the cost applicable to protecting the Federally owned frontage plus one-third of the first cost of measures for the restoration and protection of the other publicly owned portions of the shore in Orange County, California from San Gabriel River to Los Patos Avenue in Sunset Beach. The estimated first cost and Federal share are respectively for Seal Beach $186,000 and $62,000 and for Surf Side and Sunset Beach $300,000 and $86,400.

The Chief of Engineers concurred in the views and recommendations of the Beach Erosion Board.

AUTHORIZED COOPERATIVE BEACH EROSION STUDIES

MASSACHUSETTS

PEMBERTON POINT TO GURNET POINT. Cooperating Agency: Department of Public Works.

Problem: To determine the best methods of shore protection, prevention of further erosion and improvement of beaches, and specifically to develop plans for protection of Crescent Beach, the Glades, North Scituate Beach and Brant Rock.

CONNECTICUT

STATE OF CONNECTICUT: Cooperating Agency: State of Connecticut (Acting through the Flood Control and Water Policy Commission)

Problem: To determine the most suitable methods of stabilizing and improving the shore line. Sections of the coast are being studied in order of priority as requested by the cooperating agency until the entire coast has been included.

NEW YORK

FIRE ISLAND INLET AND VICINITY; Cooperating Agency: Long Island State Parks Commission.

Problem: To determine the most practicable and economic method of providing adequate material to maintain the shore in a suitably stable condition and an adequate navigation channel at Fire Island Inlet.

N. Y. STATE PARKS ON LAKE ONTARIO. Cooperating Agency: Department of Conservation, Division of Parks.

Problem: To determine the best method of providing and maintaining certain beaches and preventing further erosion of the shore at Fair Haven Beach and Hamlin Beach State Parks, and the Braddock Bay area owned by the State of New York.

NEW JERSEY

STATE OF NEW JERSEY. Cooperating Agency: Department of Conservation and Economic Development.

Problem: To determine the best method of preventing further erosion and stabilizing and restoring the beaches, to recommend remedial measures, and to formulate a comprehensive plan for beach preservation or coastal protection.

DELAWARE

STATE OF DELAWARE: Cooperating Agency. State Highway Department.

Problem: To formulate a comprehensive plan for restoration of adequate protective and recreational beaches and a program for providing continued stability of the shores from Kits Hummock on Delaware Bay to Fenwick Island on the Atlantic Ocean.

NORTH CAROLINA

CAROLINA BEACH. Cooperating Agency: Town of Carolina Beach

Problem: To determine the best method of preventing erosion of the beach.

ALABAMA

PERDIDO PASS AND ALABAMA POINT: Cooperating Agency: Alabama State Highway Department.

Problem: To determine the best method of preventing further erosion of Alabama Point, for stabilizing the inlet, and for determining the extent of Federal aid, if any, in the cost of such proposed plans for protection and improvement as may be recommended.

LOUISIANA

GRAND ISLE. Cooperating Agency: Department of Public Works, State of Louisiana.

Problem: To determine the best method of preventing further erosion of the beaches along the Gulf shore ofGrand Isle.

CALIFORNIA

STATE OF CALIFORNIA. Cooperating Agency: Department of Public Works, Division of Water Resources, State of California

Problem: To conduct a study of the problems of beach erosion and shore protection along the entire coast of California. The current studies cover the Santa Cruz and San Diego areas.

WISCONSIN

KENOSHA. Cooperating Agency: City of Kenosha.

Problem: To determine the best method of shore protection and beach erosion control.

MANITOWOC-TWO RIVERS. Cooperating Agencies: Wisconsin State Highway Commission, Cities of Manitowoc and Two Rivers.

Problem: To determine the best method of shore protection and erosion control.

TERRITORY OF HAWAII

WAIMEA & HANAPEPE, KAUAI. Cooperating Agency: Board of Harbor Commissioners, Territory of Hawaii.

Problem: To determine the most suitable method of preventing erosion, and of increasing the usable recreational beach area, and to determine the extent of Federal aid in effecting the desired improvement.